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Bike Infrastructure Evaluation of Midtown Atlanta,

A GIS and Statistics Based Study

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Contents

Introduction

Metro Atlanta has experienced a surge in population growth in the past few decades. Midtown is one of the most attractive neighborhoods to companies, businesses, and residents, new and old. From daily observations to Census data, today Atlanta's transportation network is still heavily dependent on cars for commute. The growing need for cars will lead to further traffic congestion, air pollution, and pressure to increase road infrastructure.

Studies from many organizations and institutes have shown the great benefits of biking for individuals. Better Health in Victoria, Australia identified three major benefits of biking: protection from serious diseases; personal enjoyment of low-impact exercise; and the ease of fitting it into trips to shops, school, and work (Betterhealth Channel, 2018). Another huge benefit of encouraging non-motorized transportation modes is the reduction of carbon emissions, which will lead to a more sustainable and environmentally-friendly city. Therefore, encouraging biking in Atlanta is very important.

This paper examined and quantified the bike-related infrastructure score for each street segment of Midtown Atlanta using several variables related to bike infrastructure. The bike infrastructure score was then mapped and evaluated to real-world scenarios. All data were extracted and collected from publicly-accessible data sources. In this study, good bike infrastructure of a street segment is considered safe, convenient, visually interesting, and easy to access. Factors that make up good bike infrastructure include mild elevation change, protected bike lanes, proximity to bikeshare docks, and others. Even though demographic factors and land use factors are relevant to people's choice of transportation, they do not necessarily reflect the street infrastructure itself. This study aims to address the following questions: which streets in Midtown have better or worse bike infrastructure? Where are bike facilities located in Midtown? Are the scores reflecting real-world scenarios?

Literature Review

A lively and diverse literature in this field provides support and inspiration for this study. The following literature review addresses several questions:

- **Why is bike-riding a good idea?**
- **What are the current resources for cyclists in Midtown Atlanta?**
- **What type of environment and infrastructure is considered friendly to bikes?**
- **How are bike-related variables scored and how reliable is the scoring system?**
- **What are the GIS techniques and tools in support of evaluating bike infrastructure?**
- **What are the benefits of such study to different groups of people?**

- **Why is bike-riding a good idea?**

Biking is considered the greenest transportation mode according to many scholars. First, many have studied the physics and basic character of biking. In their article*, Use of Entropy to Analyze Level of Service of Dedicated Bike Lanes in China*, Liang (Liang, 2017) analyzed the characteristics of bike users on dedicated bike lanes. Each individual bicyclist and his or her bicycle together is abstracted as an ellipse, and the reactive zone is associated with the speed and size of bicycles. In China, dedicated bike lanes are a special type of bikeways. They are physically separated, and they allow bicyclists to ride side-to-side at 15 mph (Liang, 2017). In the United States, however, dedicated bike lanes are limited in width, normally measuring less than 6 feet. Therefore, bicyclists in the United States travel slower than bicyclists in China. Based on the limited resources of bike infrastructure, lots of cities around the world are paying attention to improving bike facilities and initiating bike friendly programs. From Schumacher's article *Building Bicycle Friendly Communities: A Case Study of Five Midwestern Communities*, we know that a lot of bike-related programs are happening in Midwestern communities, including bicycle education for school children, bicycle maintenance classes, among others (Schumacher, 2013).

The costs and benefits of biking are discussed in many studies as well. According to *Evaluating Active Transport Benefits and Costs*, "Walking and cycling provide basic mobility, affordable transport, access to motorized modes, physical fitness and enjoyment. Improving active transport conditions benefits users directly, and benefits society overall, including people who do not currently use walking and cycling facilities" (Litman, 2014). Cycling's positive effects on people's life and health is discussed by Sayers. According to the article, *Bike, Walk, and Wheel, A Way of Life in Columbia, Missouri, Revisited,* "Both leisure-time and transportation physical activity have been shown to be related to access to recreational facilities as well as the characteristics of infrastructure related to walking and cycling, such as adequate sidewalks, trails, and striped lanes on roads. Exposure to elements of the physical environment also have been shown to contribute to health-related indices such as BMI" (Sayers, 2012). Thistle also discussed in his thesis paper, *Build It: A Feasibility Study Of GIS-Based Analyses of Cycling Infrastructure About the Importance of Environmental, Economic and Public Health Influences on Biking*, "A sophisticated model which attempted to account for all of the co-benefits of cycling concluded that when governments promoted cycling, they gained back between six and 24 times their monetary cost in long-term benefits, once the public health, environmental and congestion benefits were converted to monetary value" (Thistle, 2016).

- **What are the current resources for cyclists in Midtown Atlanta?**

There are lots of organizations and groups that have been analyzing and providing bikers in Atlanta with information and tools about bike lanes, recommended routes, and other information. Midtown Alliance provides the public with a map of Midtown's Bike Lanes. In the map, bike boxes and turning facilities, suggested routes, uphill arrows and Relay Bike Share Stations are mapped for the biker's convenience. This map (Figure 1) was published in 2017 (Midtown Alliance, 2017).

Figure 1: Midtown Bicycle Routes (Midtown Alliance, 2017)

The Atlanta Bike Coalition created a bike suitability map that categorizes roads into three levels of difficulty for cyclists. Their map also identifies short connections, bike stores, and one-way streets. This map provides a similar product of this study. However, the biking difficulty is categorized without actual scores. This map was published in 2013 (Atlanta Bike Coalition, 2013).

The Atlanta Regional Commission visualizes Relay Bike Share public data of trip records between September 2017 and June 2018 in Tableau. These visualizations show where most trips started and ended, as well as destination counts by designated starting hubs. Overall, this study informs the public of the basic pattern of bike share activities in Atlanta (Atlanta Regional Commission, 2018).

Midtown Alliance released The Midtown Transportation Plan in February 2017. In the plan, future bike facility improvement projects are described. Proposed improvements include traffic light enhancement, urban design improvements, street realignment, and access enhancement in various locations in Midtown (Midtown Alliance, 2017).

Cycle Atlanta is a smartphone app that collects bike data. Cycle Atlanta provides an interactive map to show where people are biking in Atlanta. Users can click on each road to see how many trips have been taken by Cycle Atlanta users. The result shows which roads are preferred by cyclists (Cycle Atlanta, 2019).

- **What type of environment and infrastructure is considered friendly to bikes;**

How will people choose their travel mode? Studies have shown that certain aspects of the urban environment have a significant influence on whether people choose to walk or bike. According to Cervero's article, *Walking, Bicycling, and Urban Landscapes: Evidence from the San Francisco Bay Area*, "Stronger evidence on the importance of urban landscapes in shaping foot and bicycle travel is needed if the urban planning and public health professions are to forge an effective alliance against car-dependent sprawl." Interestingly, Crane's study found that neighborhood design would not contribute to more bike trips when controlling for land uses and densities around the trip origin, trip costs, and traveler characteristics. Rather, the study brought people's attention to circumstances of each design rather than the rhetoric of an otherwise intuitive and potentially attractive planning initiative (Cervero, 2003 and Crane, 1998).

According to the characteristics of biker behaviors and several surveys conducted in Portland, Oregon, people found "again and again that the number one reason people do not ride bicycles is because they are afraid to be in the roadway on a bicycle" (Geller, 2007). In Dondi's *Bike lane design: the context sensitive approach*, "Cyclists form one of the most vulnerable groups of road users. So, the design of safe infrastructures for all traveler's categories, included the cyclists, becomes a primary requirement" (Dondi, 2011) Therefore, safety is the major concern for most bikers. A study in Seattle talked about good bike route parameters: slow speeds and stop signs, speed humps, placemaking, signs and markings, among others (Miller, 2017). The type of bike lanes is also considered important (Dondi, 2011).

Bicycle Level of Service (BLOS) is a nationally-used measure of on-road bicyclist comfort level as a function of a roadway's geometry and traffic conditions. Ride Illinois provides an online tool to convert variables into a score of service. The variables include number of lanes, speed limits, and other parameters (RideIllinois, 2018).

- **How are bike-related variables scored and how reliable is the scoring system?**

Using statistical methods to build models using variables identified in the previous step is helpful in evaluating bike infrastructure of a large geographic area. Discussions of the formation of such statistical model are abundant. The roles of variables, determinants, moderators in the model of influences on physical activities are introduced by Bauman (2002). In his article, *Toward a Better Understanding of the Influences on Physical Activity: The Role of Determinants, Correlates, Causal Variables, Mediators, Moderators, and Confounders*, he defined three types of correlate variables. "Mediator—an intervening variable that is necessary to complete a cause–effect link between an intervention program and physical activity. Confounder—a confounding variable is associated with the outcome, physical activity, but is also associated with exposure to the program, and will influence the strength of the observed association between program and physical activity. Moderator—an interaction variable that affects the direction, strength, or both of the relationship between an intervention and mediator or mediator and physical activity; stratification by the moderator variable will show different strength relationships between the program and physical activity behavior" (Figure 2). This article will help identify different variables.

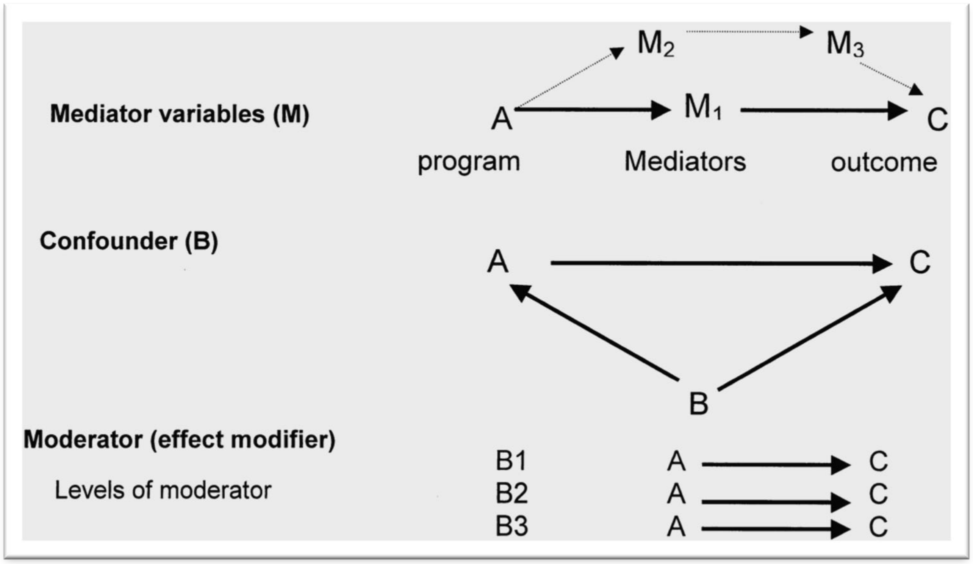


Figure 2: Variable diagram. (Bauman, 2002)

After understanding the role of variables, quantifying the built environment is the next assignment. Moudon's article, *Walking and Bicycling: An Evaluation of Environmental Audit Instruments* (Moudon, 2003) reviewed existing environmental audit instruments used to capture the walkability and bikability of environments. "It synthesizes the current state of knowledge in quantifying the built environment. Existing instruments together assemble a large set of variables measuring physical environments associated with walking and bicycling. However, no single instrument covers all constructs of the behavioral model of environments described in this work."

Among the existing infrastructure evaluation models, most of them used regression models. For example, in Golroo's *Alternative Modeling Framework for Pervious Concrete Pavement Condition Analysis*, several regression models (linear, quadratic, and exponential) were built depending on quantitative measurements that define the quality of pervious concrete conditions, where the dependent variable was surface distress rating. Afterwards, the linear regression model was chosen to develop a pervious concrete condition index (Golroo, 2011). The research diagram is illustrated in figure 3.

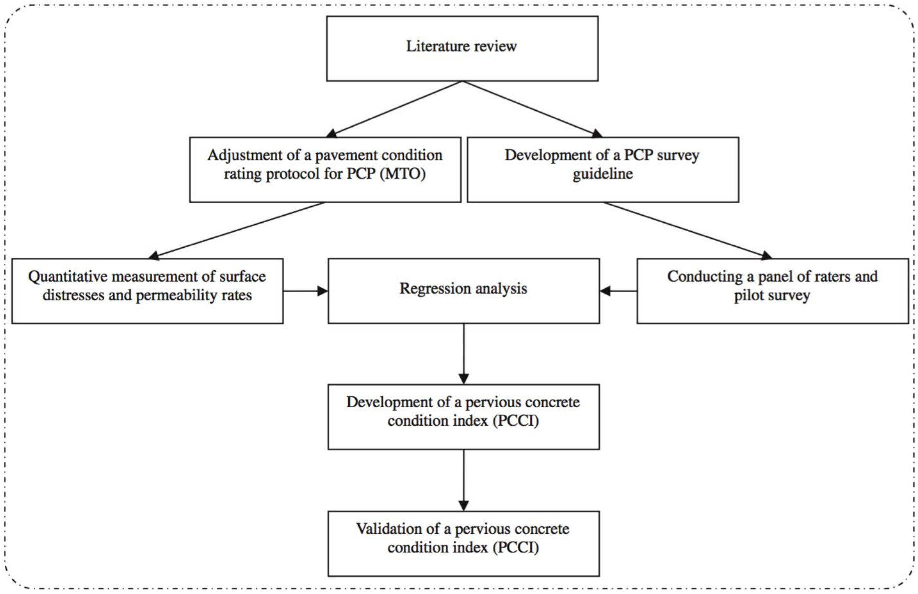


Figure 3: Research diagram. (Golroo, 2011)

Additionally, factor analysis is a good way to identify the relationships among various variables. Building such a model using factor analysis shows statistical significance in certain areas. Cervero's article *Walking, Bicycling, and Urban Landscapes: Evidence from the San Francisco Bay Area* used factor analysis to represent the urban design and land use diversity dimensions of built environments in San Francisco. In the study, variables were categorized into four factors: pedestrian-/bike-friendly design factor of origin, pedestrian-/bike-friendly design factor of destination, land use diversity factor of origin, and land use diversity factor of destination while using control variables, like steep terrain, that gauge impediments to walking and bicycling. The result was the coefficient of each variables predicting the probability that a trip would be made by walking/biking (Cervero, 2003).

In addition to regression models, simple weighted summary of normalized variables is also an effective and relatively easy way of building such model. Frank's study, *The Development of A Walkability Index: Application to The Neighborhood Quality of Life*, developed a walkability index that is composed of four elements. The walkability index was the sum of the *z*-scores of the four urban form measures, as stated in the following expression:

Walkability = [(2*z-intersection density) + (z-net residential density) + (z-retail floor area ratio) + (z-land use mix)]

The street connectivity *z*-score was weighted by a factor of two within the walkability index. The model was tested in King County, Washington and five counties in the Baltimore-Washington, DC region and received good performance (Frank, 2010).

Though for most of the statistical model studies, the authors provided the parameters for each variable, these parameters were calculated according to the unique sample in their study area. Therefore, a simple copy of the parameters is not applicable in this study for Midtown Atlanta. However, the methods of grouping, including, extracting, and processing of the variables will be used in this study.

- **What are the GIS techniques and tools in support of evaluating bike infrastructure?**

Online maps provide the public with suggestions of where to bike. Portland By Bicycle is an online map that shows the location of bike lanes and routes, climbs, difficult intersections, bike shops, and one-way streets (Portland, 2018).

Masli discussed that the Geowiki route analysis tool in GIS can support identifying disconnections of network, which will be helpful in transportation planning (Masli, 2013). Chaudhari in his paper, *GIS as a Sketch-Plan Tool to Replace Traditional Transit Route Planning Practice for College and University Communities*, discussed how to use GIS to aggregate data and calculate service area for a transit system. They aggregated the existing transit routes, parcels, streets, with where students live, identifying underserved students' locations near Auburn University, Alabama. This inexpensive, reliable, and accurate analysis will help the university transit authorities to make decisions (Chaudhari, 2010). Shofi's *An Empirical Analysis of Bike Safety in Lawrence Using Road Geometry and Traffic Characteristics* used road geometry, environmental characteristics, infrastructure, traffic characteristics, and characteristics of drivers/bicyclists to analyze bike route safety. Factors of road geometry, including route slope and curvature, are calculated in GIS software (Shofi, 2017). As a result, assistance from GIS tools is essential in this type of study (Figure 4).

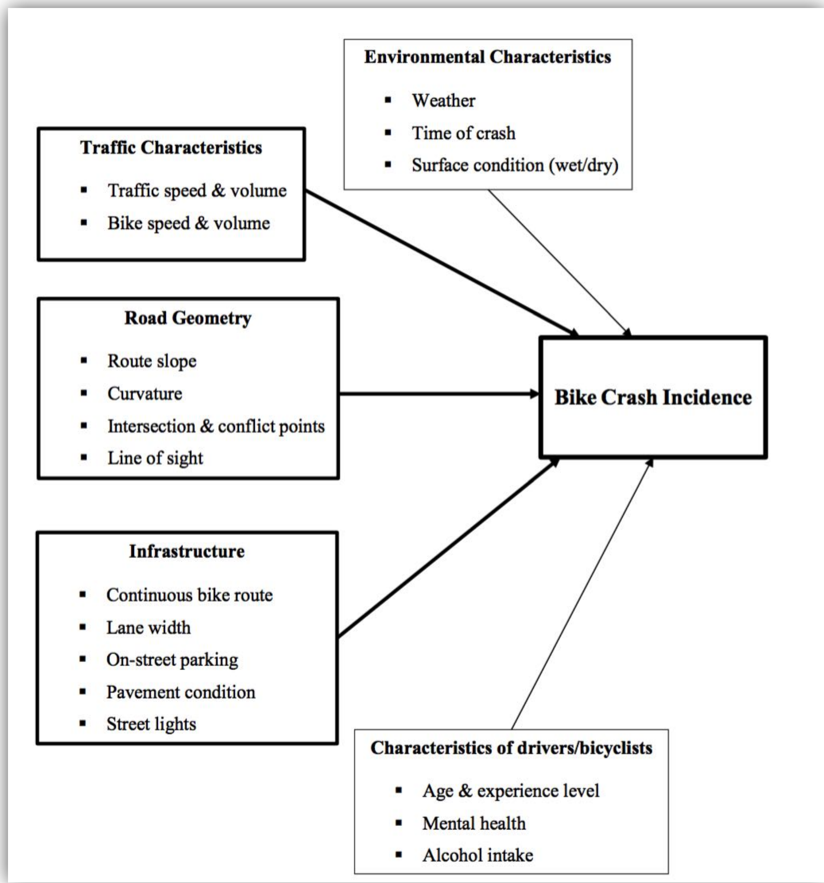


Figure 4: Bike Crash Incidence diagram. (Shofi, 2017)

- **What are the benefits of such study to different groups of people?**

The bike score will give people suggestions on where to bike and provide suggestions to the city of where to implement infrastructure improvement projects.

Additionally, promoting cycling could help increase tourism for the city as well if bike infrastructure is adequately supported by policies. Chen's article, *How to Promote Bike Tourism*, constructed a framework composed of 7 aspects and 69 items to promote Taiwan's bike tourism globally (Chen, 2017).

With the emergence of scooters and other electric-aided, non-motorized, casual travel tools, the importance of supporting city infrastructure and policies is evident. Studies have shown that infrastructure and policies related to cycling greatly influence people's lives. For example, a study in Brighton, United Kingdom, reported that about three-quarters of residents who used shared bikes made regular use of them, there were significant associated reductions in car driving; and there were positive impacts related to the propensity to cycle (Cairns, 2017).

Therefore, studies on bike infrastructure are beneficial to everyone in the city, both now and in the future as the establishment of more green and shared transportation modes increases.

Methodology

- **Datasets used in this study and sources:**

Variable	**Source**	**Description**
Street Central Line Segments	Tiger (2019)	Street central line shapefile.
Bike lanes	Midtown Alliance (2017)	Bike lane type: dedicated bike lane or sharrow.
Road Class	Open Street Map (2019)	Class of road.
Road Speed Limit	Open Street Map (2019)	Highway and road with high speed limit are considered unfriendly to bikers.
Midtown Neighborhood Boundary	Tiger (2019)	Boundary of Midtown Neighborhood.
Traffic Proximity	EJSCREEN (2019)	Average annual daily traffic by proximity.
Traffic Volume AADT	GDOT (2019)	Annual average daily traffic.
Relay Bike Hub	Atlanta Department of City Planning GIS (2019)	Relay bikeshare docks location.
Bike Rack, Bike Station	Google Street View (2019)	Locations of bike racks and bike stations.

Slope	Fulton County Topographic Contours Download Tool (2019)	Elevation change divided by length of segment.

In order to create the bike infrastructure map, each sub-score is assigned to each street segment using a geographic information system (GIS). Street centerlines within the Midtown neighborhood boundary were extracted and initially cleaned. The original street centerline shapefile contained a noticeable number of small segments that were less than 100 feet. The existence of these segments would lead to inaccuracy in data counts and statistics. Therefore, a filter of shape length >= 100 feet was executed to exclude the small segments. The next step involved bringing in other bike facility layers and determining the appropriate scoring method. In this study, there are 8 variables being considered and 7 variables being calculated:

- The bike lane layer was assigned a value by comparing it with Midtown Alliance Bike Route Map. Street segments without bike lanes were assigned 0, roads with sharrows were assigned 1, and roads with dedicated bike lanes were assigned 2. After the initial GIS analysis, the results were verified through Google Street View. The Midtown Alliance Bike Route Map is up to date and accurate according to the Google Street View verification in March 2019.

- The Relay bike station layer score was evaluated based on if the road was within 0.2 mile of a Relay bike dock. As a rule of thumb, 0.25 mile is considered a distance within which people are likely to walk. However, considering the actual trip length is longer than the Euclidean distance on maps, 0.2 mile was used in this study to adjust the error. The Relay Station location shapefile was downloaded from the City of Atlanta's GIS Department and verified through the Relay website. A 0.2-mile buffer around the bike stations was created, and street segments within the buffer zone area were assigned a score of 1, while those that were not were assigned 0 (Figure 5).

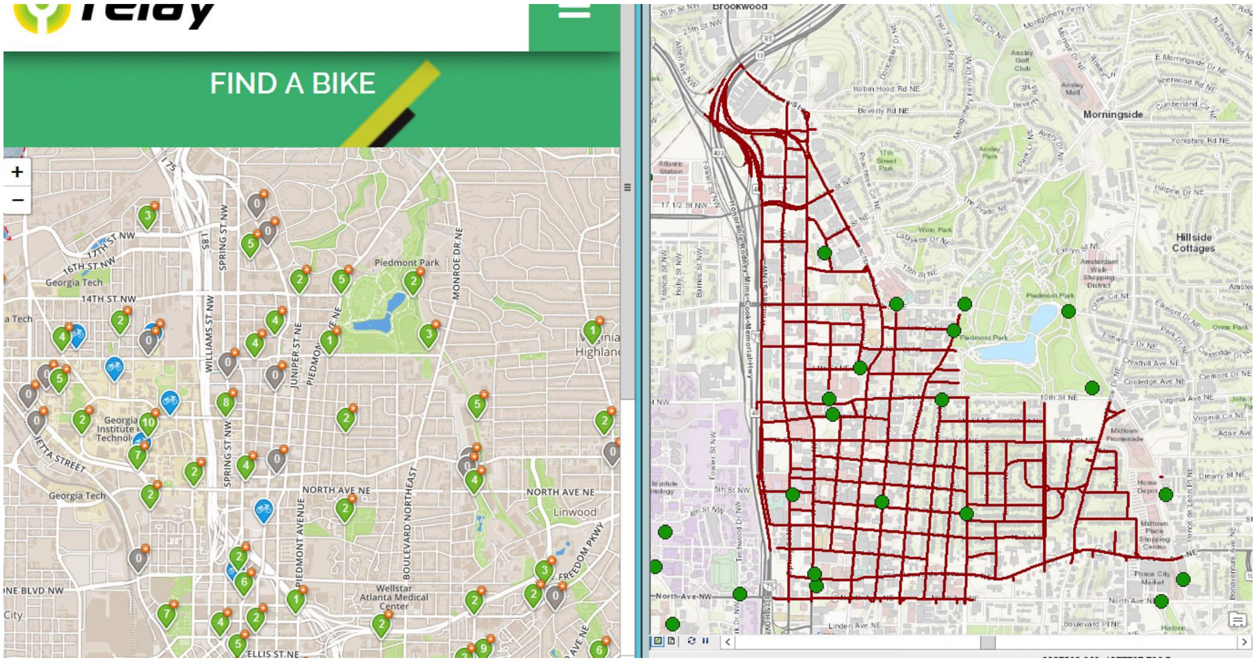


Figure 5: Verifying Relay Hub Locations.

- Currently, there is not an open source bike rack location map or shapefile. Some bike rack information can be found on Relay website but most of it is missing. Therefore, a Google Street View survey was conducted to manually locate all the bike racks. Images in the Midtown area were captured between January and May 2018. A Google Maps search of bike shops was also conducted and the locations for bike shops were located as well. As a next step, a 0.2-mile buffer zone was created based on bike rack and shop points. Street segments within the buffer zone area were assigned a score of 1, otherwise they received 0.

- The slope of each street segment was determined by taking the difference of elevation at the start and end point of the segment, then dividing by the length of the segment. The elevation information was extracted from Fulton County contour lines. The contour lines were converted into TIN layers in ArcGIS, and the slope was calculated by spatial joining the TIN and the road central line shapefile. The result of the slope score was calculated as the actual slope rather than an assigned categorical score.

- Traffic proximity was determined by the traffic proximity variable calculated by EJSCREEN. The variable consists of the vehicle count (average annual daily traffic) at major roads within 500 meters (or nearest neighbor outside 500 meters), divided by the distance in kilometers (km). EJSCREEN calculates this at the block group level. However, a lot of roads and streets serve as the boundaries of block groups. The scores of those roads were determined by verifying against Annual Average Daily Traffic (AADT) extracted from the Georgia Department of Transportation's Traffic Analysis and Data Application. If a high AADT count appeared on a road, the traffic proximity score of that road was assigned the value of the higher EJSCREEN traffic proximity score.

- The road class was determined by OpenStreetMap data. In Midtown, there are four types of roads: primary, secondary, tertiary, and residential. Their corresponding scores are 0, 1, 2, 3.

- The road speed limit was determined by OpenStreetMap data. However, only some of the roads in the OpenStreetMap database had speed limit information. Therefore, the mean value of existing speed limits for each road class and the location of the roads were used when assigning speed limit to the street segments with missing speed limit value. As a result, for all the roads missing speed limit information, some primary roads, all secondary roads and all tertiary roads were assigned a speed limit of 48 mph, highways were assigned 88mph, and residential roads were assigned 40 mph.

- The streetlight score was determined by a Google Street View Survey. However, after surveying all the roads, every street in Midtown neighborhood has good streetlights. Fortunately, this indicates that Midtown has good streetlight infrastructure. Unfortunately, the inclusion of this variable won't affect the score. Therefore, the prevalence of streetlights was examined but not calculated in the study.

Statistical summaries and histogram of all the variables are illustrated below:

Number of street segments: 416

Road Class variable (Figure 6):

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.000	1.000	2.000	1.752	3.000	3.000

Bike Lanes Variable (Figure 7):

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.0000	0.0000	0.0000	0.2548	0.0000	2.0000

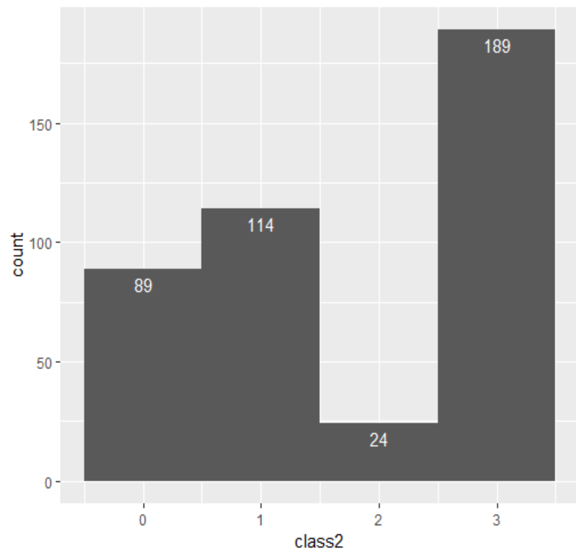


Figure 6: Road Class Variable histogram.

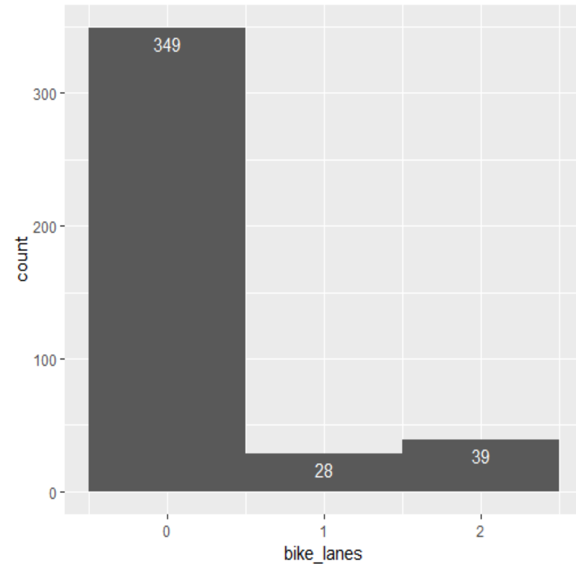


Figure 7: Bike Lane variable histogram.

Slope (Figure 8):

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.000	1.609	2.897	3.207	4.496	12.189

Bike Station (Figure 9):

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.0	0.0000	1.0000	0.5457	1.0000	1.0000

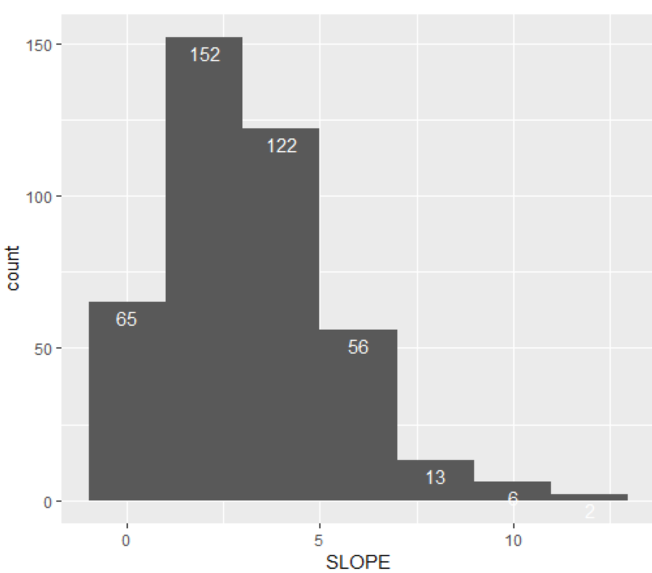


Figure 8: Slope variable histogram.

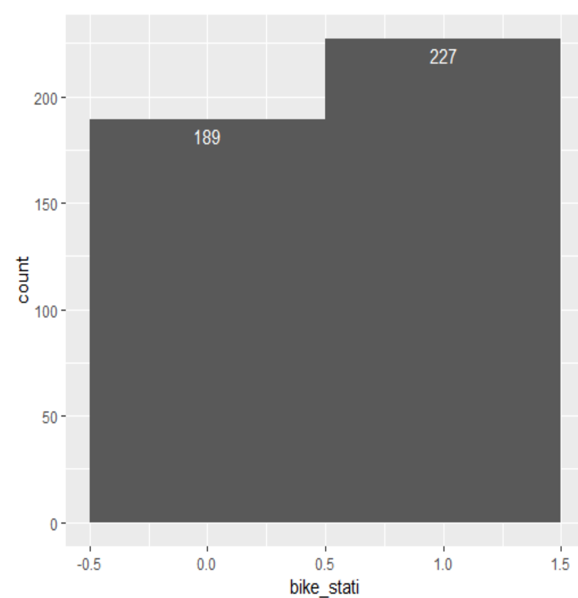


Figure 9: Bike station variable histogram.

Traffic proximity (Figure 10):

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
150	830	1700	6002	15000	18000

Bike rack and store (Figure 11):

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
0.0000	1.0000	1.0000	0.8365	1.0000	1.0000

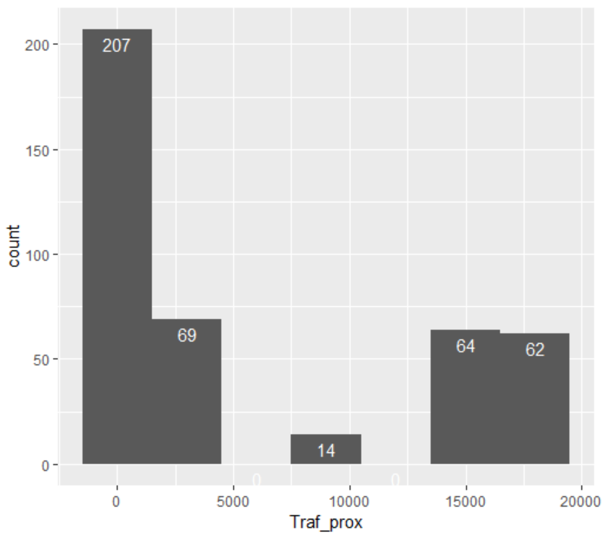


Figure 10: Traffic proximity variable histogram.

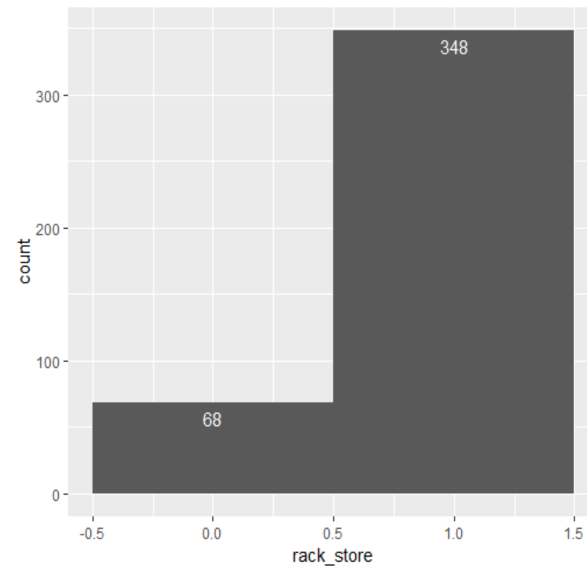


Figure 11: Bike rack and store histogram.

Speed Limit, mph (Figure 12):

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
40.00	40.00	48.00	47.88	48.00	88.00

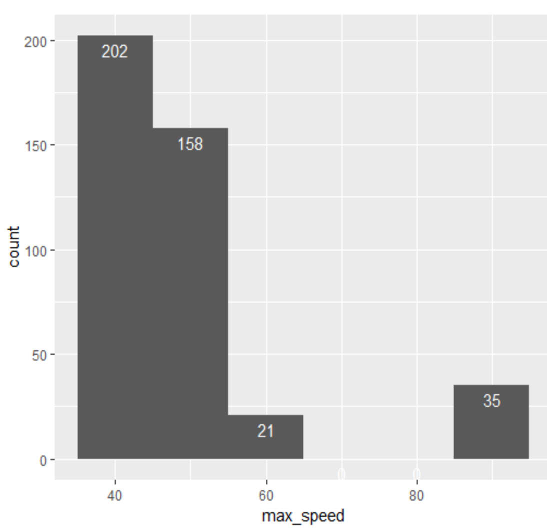


Figure 12: Speed limit variable histogram.

- **Data processing and aggregation:**

The next step was to scale the numeric variables. Slope and traffic proximity variables were scaled in RStudio to range 0-1. Due to the special relationship between speed limit and actual harm, the influence of speed limit is related to the square of speed (v^2) rather than the speed itself. According to the European Commission, "The braking distance is proportional to the square of speed (v^2)" (European Commission, 2019). Therefore, speed limit values were squared and then scaled in RStudio to range 0-1.

The third step was to determine the aggregation model of these variables. Principal Component Analysis (PCA) was conducted in RStudio initially to test the combination. The result of PCA is as follows (Table 1):

Importance of components:

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Standard deviation	**1.4752**	**1.1595**	**1.0380**	**0.9667**	**0.79167**	**0.65142**	**0.64522**
Proportion of Variance	**0.3109**	**0.1921**	**0.1539**	**0.1335**	**0.08953**	**0.06062**	**0.05947**
Cumulative Proportion	**0.3109**	**0.5030**	**0.6569**	**0.7904**	**0.87991**	**0.94053**	**1.00000**

Table 1: Principal component analysis indices.

Whereas:

PC1 to PC 7 represent:
bike station (categorical variable)
bike rack (categorical variable)
bike lane (categorical variable)
slope (scaled)
traffic proximity (scaled)
speed (scaled squared)
road class (categorical variable)

As we can see from the table, the bike station variable explained about 31% of the combination of the score, whereas the bike lane variables only explained 19% of the score. Therefore, using PCA analysis was not the most appropriate way of combining variables in this situation because some variables are deemed more important than other variables in real world scenario according to rule of thumbs and literature review.

Additionally, after studying Shofi's article, it was learned that without the dependent variable, like bike crash data, a linear regression is not the best way to do this type of analysis. As a result, a simple weighted sum method was used and the weighted constants were determined by several existing studies.

Independent Variable	Exponentiated Coefficients: NB	Exponentiated Coefficients: ZINB	
		Count Model	Logistic Model
Speed	0.96 **	0.94 **	1.03
Slope	0.83 **	0.99	1.19
Lane	1.51 ***	0.89	0.34 ***
Bike Route	1.38	0.41 **	0.17 ***
Volume_Collector	0.83	0.51	0.56
Volume_Street	0.34 **	0.28 **	0.55

Significance Code (α): 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

Figure 13: Coefficients table. (Shofi, 2017)

In order to determine the weights of each variable, proportions of these variables in previous studies have been analyzed to extract and form a reasonable combination of the score.

In Shofi's study (Figure 13), the bike safety coefficients ratio of bike lane to slope to speed is roughly 3:2:2. In the Ride Illinois Bike Level of Service (LOS) Calculator, the model is:

$$\text{Bicycle LOS} = a_1 \ln\left(Vol_{15}/L_n\right) + a_2 SP_t(1+10.38HV)^2 + a_3(1/PR_5)^2 + a_4 (W_e)^2 + C$$

Where: Vol15 = Volume of directional traffic in 15-minute time period and $a_1 = 0.507$.

Traffic Volume (ADT) variations (T-statistic = 5.689)

ADT	=	1,000 Very Low	2.75	31% decrease
ADT	=	5,000 Low	3.54	11% decrease
ADT	=	12,000 Average (baseline) - - - - - - - -	3.98 - - - - - -	no change
ADT	=	15,000 High	4.09	3% increase
ADT	=	25,000 Very High 4.35	9% increase	

Figure 14: Traffic Volume variations. (RideIllinois, 2018)

As shown in the report (Figure 14), a 25% increase in traffic volume would lead to 3% increase of the LOS score.

Furthermore, according to Cervero's study of factors that would influence the probability that a trip will be made by bicycle, slope was the top negative influential factor with a coefficient of -7.796, whereas the absolute values of all other coefficients were all lower than 2.0 (Figure 15).

TABLE 3—Bicycle-Choice Model for Predicting the Probability That a Trip Will Be Made by Bicycle

	Coefficient	Standard Error	Probability
Constraints/deterrents			
Trip distance (miles)	−0.291	0.084	.001
Slope (rise/run)	−7.796	5.930	.187
Dark (1 = yes, 0 = no) (before sunrise or after sunset)	−0.721	0.314	.022
Low-income neighborhood (proportion of households within 1 mile of origin and destination with annual incomes < $25 000)	−1.657	1.221	.175
Personal/household attributes			
Gender (1 = male, 0 = female)	0.588	0.194	.002
African American (1 = yes, 0 = no)	0.854	0.472	.071
Number of vehicles in household	−0.629	0.120	.000
Number of bicycles in household	0.345	0.037	.000
Trip characteristics			
Weekend trip (1 = yes, 0 = no)	0.226	0.219	.301
Recreation/entertainment purpose (1 = yes, 0 = no)	0.602	0.225	.001
Social purpose (1 = yes, 0 = no)	0.861	0.281	.002
Shop purpose (1 = yes, 0 = no)	0.443	0.389	.256
Built environment characteristics			
Employment accessibility: number of jobs (in 10 000s) within 5 miles of origin	−0.017	0.011	.106
Retail/service density: number of retail/service jobs per net commercial acre within 1 mile of origin	0.005	0.003	.114
Pedestrian-/bike-friendly design factor, origin	0.234	0.151	.122
Pedestrian-/bike-friendly design factor, destination	0.193	0.113	.088
Land-use diversity factor, origin	0.156	0.098	.112
Land-use diversity factor, destination	0.056	0.099	.570
Constant	−3.773	0.392	.000

Summary statistics:

No. of cases = 7836

$\chi^2 = 152.8$ (probability = .000)

$\rho^2 = 1 - L(1)/L(0) = .131$

Figure 15: Coefficient of Bicycle-choice model. (Cervero, 2003)

Fourth, in the Seattle Neighborhood Greenway Evaluation study, the researchers thoroughly discuss the impact of speed limit and road class. They believed that the speed limit and road class would influence the safety and quality for trips made by pedestrians and bikers.

Fifth, as can be drawn by rule of thumb, the existence of dedicated bike lanes would be positively associated with increased bike facility infrastructure.

Therefore, considering these five reasons, the bike lane variable was assigned 30% significance, while slope was assigned 25%, traffic proximity was assigned 15%, road class and speed limit were assigned 15% between them, and bike station, racks, and stores were assigned 15% of significance.

The method of combining the 7 variables is illustrated in Table 2 below:

Data	**Calculation**	**Highest Possible Score**	**Lowest Possible Score**
Bike Lane	(lane)*30	30 (dedicated bike lane)	0 (no bike lane)
Bike Station	(station) * 7.5	7.5	0
Bike rack and store	(rack) *7.5	7.5	0
slope	(1-slope)*25	25 (most flat street)	0 (most hilly street)
traffic proximity	(1-prox)*15	15 (fewest traffic count)	0 (largest traffic count)
speed limit	(1-speed) * 10	10 (lowest speed limit)	0 (highest speed limit)
Road class	class * 5	5 (residential)	0 (primary)
Total		**100**	**0**

Table 2: Variable calculation method table.

After combining the scores, a bike infrastructure score map can be drawn using the score and the street shapefile. The map would illustrate the distribution of bike facilities in Midtown Atlanta. A summary of the values of the scores is described:

Score (Figure 16)

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
18.67	38.87	46.68	47.02	54.04	89.09

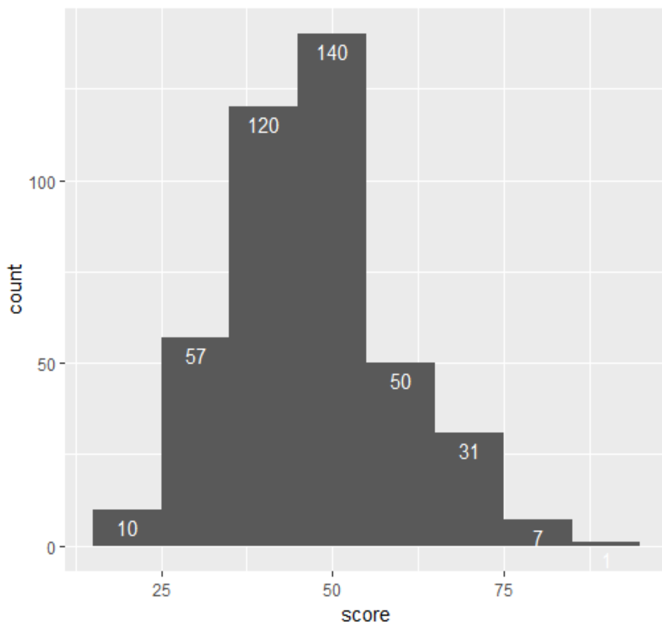


Figure 16: Final score histogram.

Discussion

After obtaining the score, two maps were created. The Atlanta Midtown Bike Score Map (Figure 17) shows the score of each street segment, as well as the Midtown neighborhood boundary, and the three MARTA stations located in the neighborhood.

The Atlanta Midtown Bike Facility Map (Figure 18) shows the location of bike lanes, Relay bike hubs, bike racks and shops, MARTA stations, the Midtown neighborhood boundary, as well as street segments with slope value higher than 7 and traffic proximity value higher than 2000.

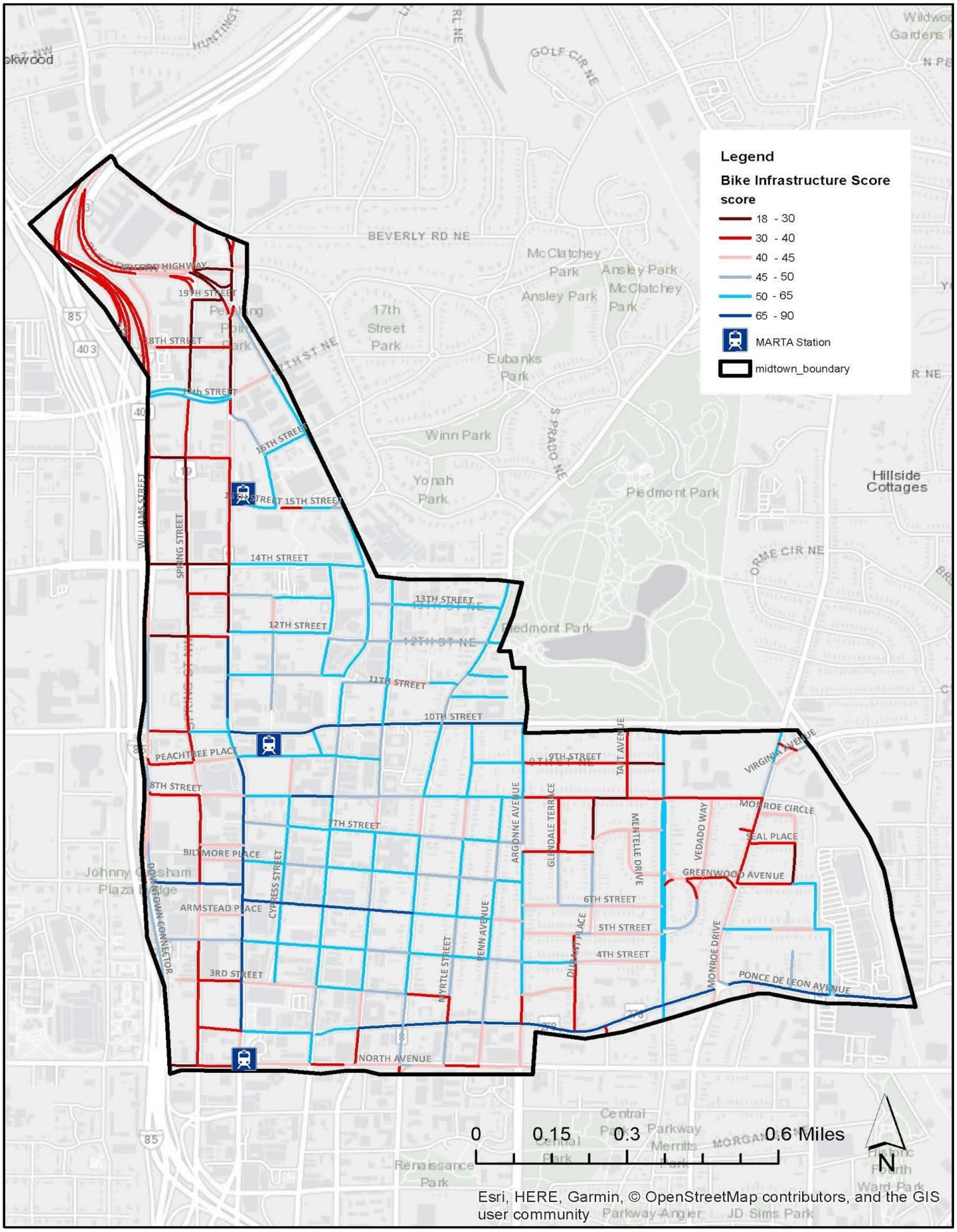


Figure 17: Atlanta Midtown Bike Score Map

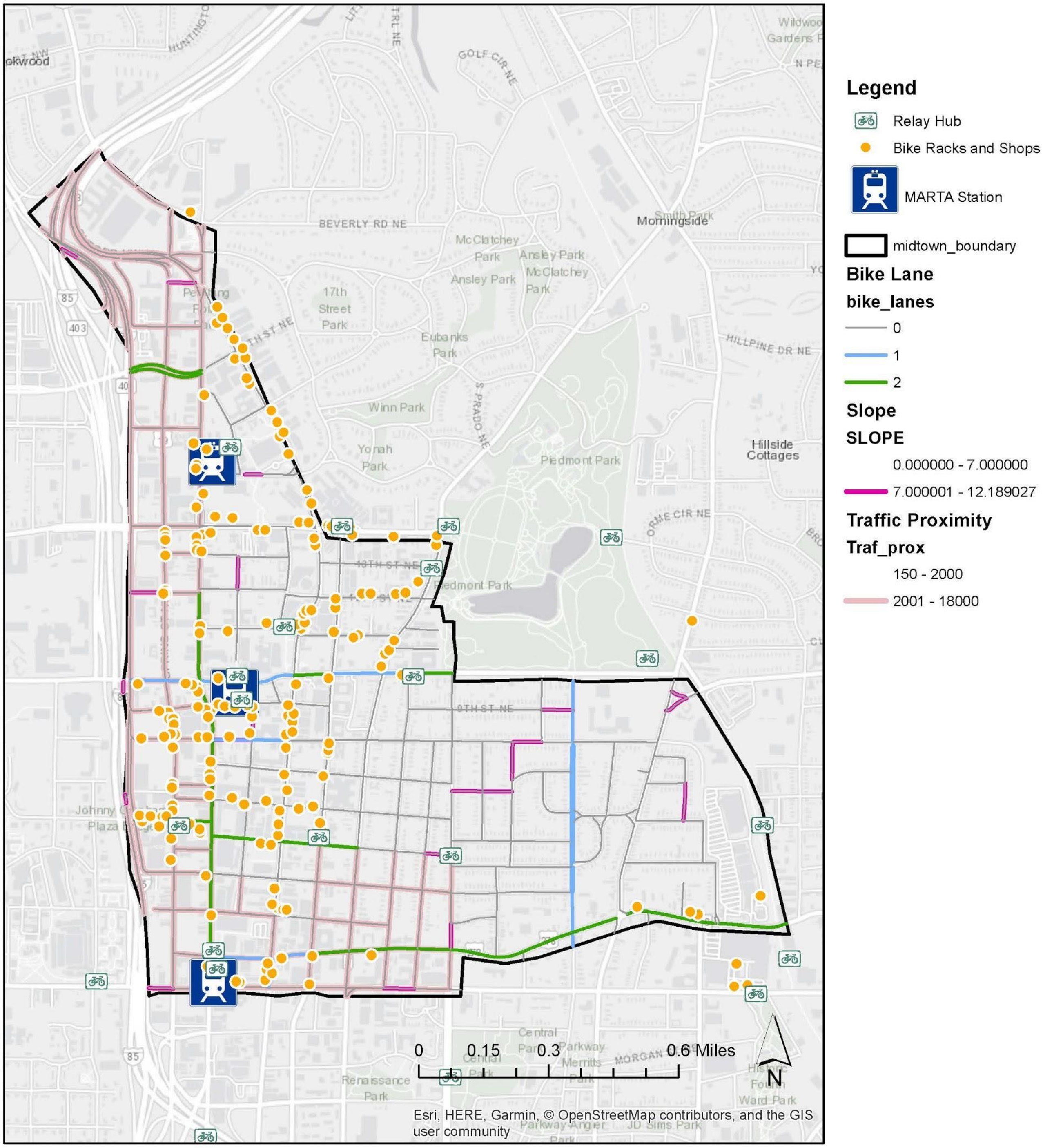


Figure 18: Atlanta Midtown Bike Facility Map

Atlanta Midtown Bike Score Map discussion:

- The overall bike infrastructure in Midtown Atlanta is not ideal. Only four roads/streets in Midtown have bike lanes. Most of the street segments in Midtown have a bike score of lower than 50.
- The street segments to the east of West Peachtree Street and to the east of Argonne Avenue have higher scores.
- The three roads with bike lanes are 5th Street, West Peachtree Street, and Ponce de Leon Avenue, and they received relatively higher scores. This implies that streets with bike lanes in Midtown also feature other good facilities.
- Street segments on the western side of Midtown have lower scores, because of the land use type of low-density residential. This area lacks bike share stations, bike racks, and bike shops.
- Street segments to the west of West Peachtree Street have lower scores, due the proximity to highways.

Atlanta Midtown Bike Facility Map discussion:

- This map shows the locations of bike share hubs, bike racks, bike lanes, hilly roads, and roads with high traffic volume. This map will give cyclists a detailed idea of where to bike and where to find bike facilities.
- Bike share hubs and bike racks are clustered in West Midtown.
- There are a lot of hilly roads in the residential area south of Piedmont Park.
- There is also a cluster of bike facilities near Ponce City Market.

Ground Truth Verifying

A field trip was conducted by the author on April 3rd, 2019 between 2-4pm. Some of the highest-scored street segments as well as some of the lowest-scored street segments were visited via bike, and the experience and photos of the trip were recorded.

5th Street between Cypress Street and Peachtree Street. Score: 84.05 (Figure 19)

This part of 5th street has dedicated bike lanes, lower traffic, and mild elevation change. It was pleasant to bike here. Therefore, the 84.05 score accurately reflected the good experience.

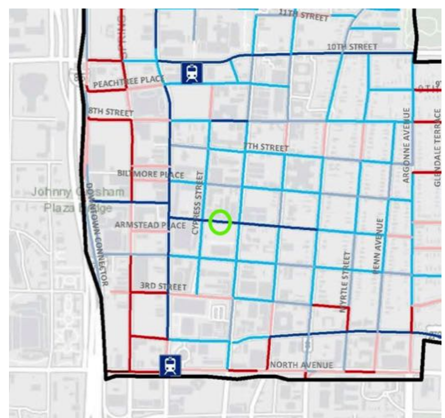


Figure 19: 5th Street between Cypress Street and Peachtree Street.

Ponce de Leon between Kennesaw Ave and Glen Iris Dr Drive. Score: 67.28 (Figure 20)

On the south side of Ponce de Leon, there is a dedicated bike lane. However, cars always drive at high speeds on Ponce de Leon, and they are close to the bike lane. The author biked here and felt unsafe due to the traffic. However, the infrastructure was better than most of the other Midtown street segments.

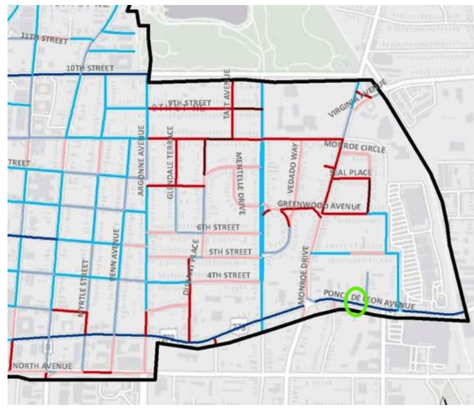


Figure 20: Ponce de Leon between Kennesaw Ave and Glen Iris Dr Drive

Intersection at 5th Street and Spring Street. Score: 70.11 (Figure 21)

Due to the proximity to Georgia Tech campus, there were a lot of cyclists at this intersection, which allows for pedestrians to cross diagonally. After a short observation period, the author found that the Georgia Tech trolley stopping at bus stops, and cars backing into the parking spots along the street will break the flow of biking. Other than those negative elements, biking near the intersection was quite pleasant.

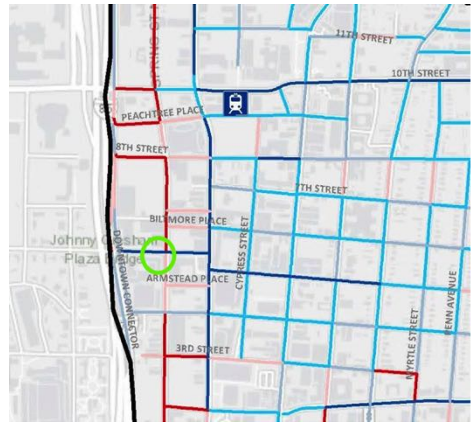


Figure 21: Intersection at 5th Street and Spring Street.

West Peachtree Street between 13th Street and 14th Street. Score: 25.24 (Figure 22)

This street segment has a huge elevation change, without bike lanes, and relatively narrow side walk. Biking here was not pleasant when going uphill.

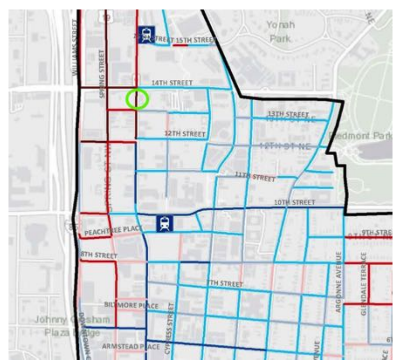
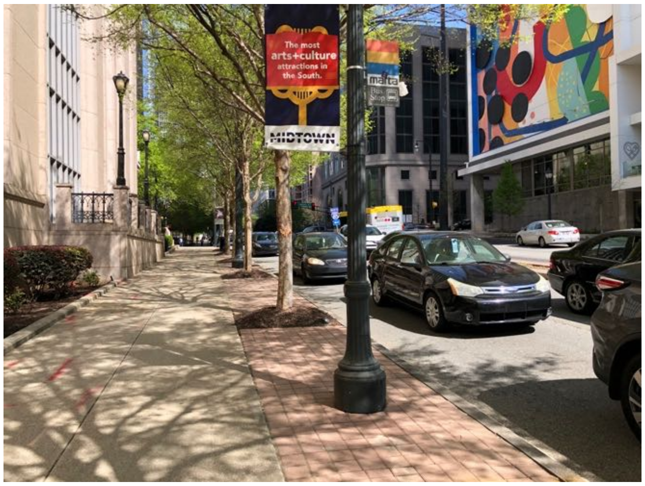


Figure 22: West Peachtree Street between 13th Street and 14th Street.

14th Street between Spring Street and West Peachtree Street. Score: 27.84 (Figure 23)

This street segment has a higher traffic volume and no bike lanes. However, the sidewalk was wide enough for bikers to walk their bikes. The moderate change in elevation made it less pleasant to bike here.



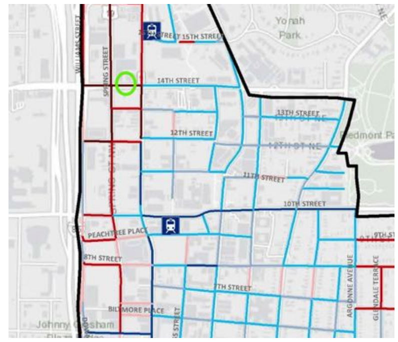


Figure 23: 14th Street between Spring Street and West Peachtree Street.

Spring Street between 14th Street and 13th Street. Score: 25.70 (Figure 24)

Cars generally travel fast on this segment, and one of the sidewalks was closed due to the building construction of the new Whole Foods grocery store. Biking here was not pleasant.

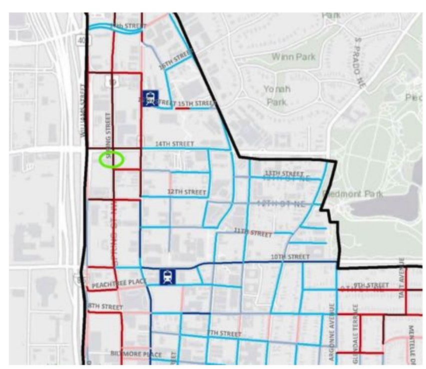


Figure 24: Spring Street between 14th Street and 13th Street.

Some general findings from the field trip are as follows:

- The score reflects the biking experience to some extent. However, the better bike infrastructure does not necessary lead to better biking experience.
- Overall, the biking experience is not ideal, whether on lower score streets or higher score streets.
- Unexpected events will drastically change the experience of biking. These events include road closures due to construction, and illegal parking (Figure 25), and sidewalk closures (Figure 26).

Figure 25: Illegal parking.

Figure 26: Closed sidewalk.

- When considering bike infrastructure, abruptly terminating bike lanes will bring an unexpected end to cyclists' trips. (Figure 27)

Figure 27: Abrupt end of bike lane.

- The width of most bike lanes in Midtown Atlanta is not wide enough for multiple bikes to yield.
- Cyclists will not feel safe on a dedicated bike lane that is adjacent to fast traveling vehicles without any separations like fences. This is especially true for Ponce de Leon between Peachtree Street and Ponce City Market.

Disparity Identification by Comparing with Cycle Atlanta

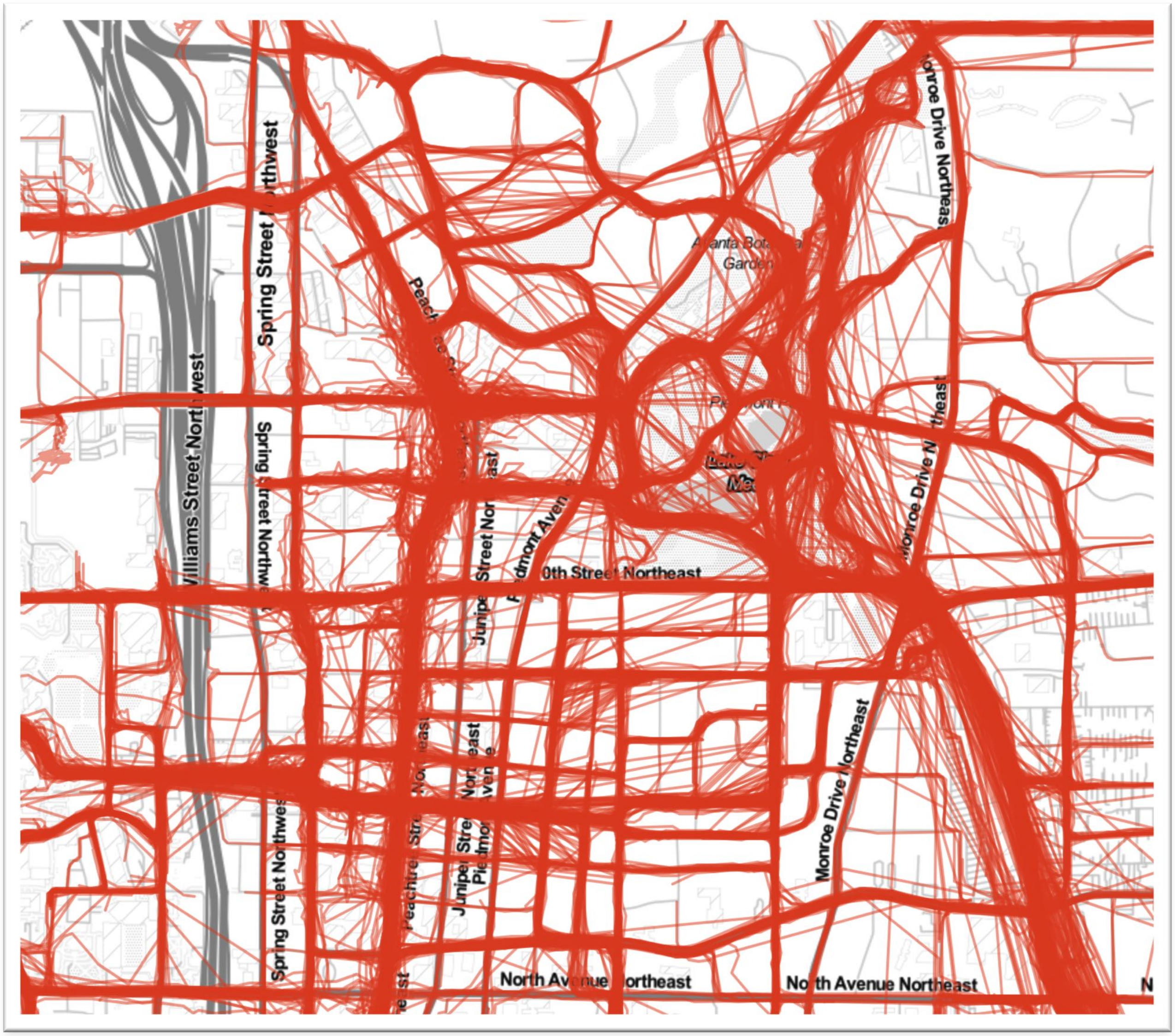


Figure 28: Cycle Atlanta map.

This Cycle Atlanta map screenshot (Figure 28) was captured on April 6th, 2019. According to the map, there were a lot of trips taken on Peachtree Street, even though there are no existing bike lanes on Peachtree Street and most street segments of Peachtree Street have scores of around or lower than 50. This can be considered a disparity between supply and need. Conversely, there were a lot of trips taken on 5th Street whereas 5th Street has dedicated bike lanes and street segments with scores around or over than 65.

Conclusion

Data scarcity is still the main limitation of the study. With little access to updated data on street measurements, bike-related crash data, opinion surveys, and other empirical data, the bike infrastructure score model likely will not be representative, and likely will not reflect all aspects of the urban environment's influences on bike riding experiences. Additionally, the model would be harder to apply to other cities or study areas.

Currently, there is no universal method for quantifying urban environment variables. Due to data scarcity, linear regression, factor analysis, or principal component analysis are not suitable for the study. Yet weighed summary method is less convincing than those methods to explain the coefficients of each variables.

The experience of biking in Midtown is generally not pleasant. Bike lanes should be planned and constructed in street segments with lower scores and street segments with higher biking trip counts. Furthermore, there are other interventions beyond improving bike-related infrastructure that the city can do to improve biking experience.

Peachtree Street was identified as the street with the highest bike infrastructure disparity. Adding bike lanes on Peachtree Street should be one of the primary concerns for Midtown Alliance regarding improved bike infrastructure.

Limitations

- The number of bikes that can be parked at each bike rack was not recorded and considered.
- This method failed to create a model like Ride Illinois Bike Level of Service Calculator. Users cannot put in their data of each variable and compute the bike infrastructure score. The individual street segment score is associated with the study area. It is only inherently meaningful to compare one street segment score with other street segment scores within the study area. Empirical comparison is less meaningful using this method.
- Some data are not up-to-date. For example, Google Street View audits used images that were captured a year ago. New constructions were not reflected in Google Street View. (However, Google Street View updated their images in the Atlanta area in the first week of April. Unfortunately, this was not reflected in this study due to time constraints.)

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